Reference Material for the UNRBA Modeling and Regulatory Support Kickoff Meeting – September 28, 2016

In 2010, the Environmental Management Commission passed the Falls Lake Nutrient Management Strategy, requiring two stages of nutrient reductions for Falls Lake. The Strategy was developed on a compressed schedule with only three years to collect data, develop watershed and lake models, and adopt the rules. Because of the uncertainty associated with the model-based load reductions, the Strategy allowed for a reexamination of the required nutrient load reductions (http://portal.ncdenr.org/web/fallslake/home). Due to this uncertainty and because the Strategy is estimated to cost over $1 billion, the Upper Neuse River Basin Association (UNRBA) began planning for a reexamination in 2011. As described below, the UNRBA has been collecting water quality data in the watershed and the lake since August 2014 and has begun planning for the modeling component of the reexamination.

The UNRBA is pleased to host its kickoff meeting for the Modeling and Regulatory Support component of the UNRBA Reexamination Project on September 28, 2016. Due to the compact agenda for the kickoff meeting, this reference material is being distributed beforehand to provide an overview of the work of the UNRBA and other organizations. Additional information is available on the UNRBA website (www.unrba.org). In an effort to conserve paper, a limited number of copies of this reference material will be available at the kickoff meeting (one per table). It is recommended that meeting participants print this document if they would like a hard copy. This reference material includes the following types of information:

- A summary of the goals and objectives established in 2010 for the original Falls Lake Nutrient Response Modeling and a summary of the monitoring goals established by the Triangle J Council of Governments in 2012. As part of the kickoff meeting, stakeholders will be asked to discuss the past goals and objectives and provide input on necessary revisions to address current issues and concerns.

- An overview of the UNRBA Monitoring Program that began in August 2014. The locations, parameters, and frequencies of the routine monitoring as well as brief descriptions of special studies are provided. During the kickoff meeting, we will provide a few examples of how the UNRBA Monitoring Program address questions from the original goals and objectives. We will not review each element of the Monitoring Program in detail during the kickoff meeting. The monitoring tab on the UNRBA website contains links to the monitoring database and summary reports that describe the data.

- A description of the types of modeling packages that will be evaluated to support the Modeling and Regulatory Support contract and a summary of the scope of work for Year 1 which includes the kickoff meeting, evaluation and selection of modeling packages to support the reexamination, and development of a Modeling Quality Assurance Project Plan. Input from the kickoff meeting will be used to inform the model evaluation and selection criteria.

The UNRBA is comprised of many watershed stakeholders, including the City of Raleigh which withdraws a large portion of its drinking water from Falls Lake. A key objective of the UNRBA is to conduct the reexamination using a measured, scientific approach with the best available information. Figure 1 provides a graphical depiction of how the monitoring and modeling projects support the reexamination of the Falls Lake Nutrient Management Strategy.

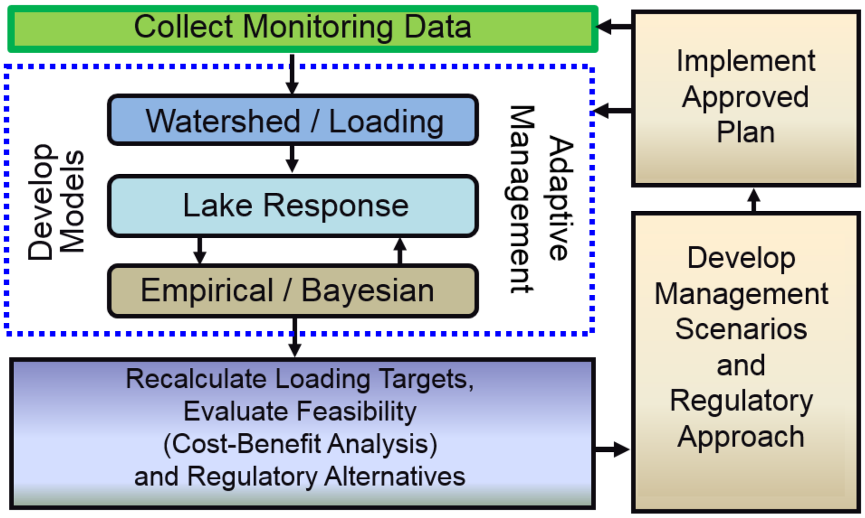

Figure 1. Adaptive Implementation of Monitoring and Modeling Efforts

Falls Lake Monitoring and Modeling Goals and Objectives

Stakeholder Meeting: September 7, 2010. Facilitator: Vickie Atkinson, City of Durham

What goals and objectives do you or your jurisdiction have for any new monitoring or modeling of Falls Lake or the Falls Lake watershed?

MUST DO

Falls Lake

- Evaluate Past, Present and Future Uses of the Lake
  - Determine if existing water quality standards support existing uses. Are they too restrictive, too loose, or missing?
  - Evaluate how well the lake meets existing uses. Water supply, aquatic life propagation, recreation (boating, swimming, fishing)
  - Evaluate the degree to which the lake has, is, or can support all it's authorized uses.
  - Understand current condition of the lake
  - Supports UAA (Use Attainability Assessment) or change in use (water quality standard) for upper Falls Lake
- Lake Response Timeline
  - Given high internal loading in the lake, how will the lake respond to changes in the load?
  - Data and analysis that can be used to forecast or "backcast" conditions
- Water Treatment Concerns
  - Relationship between TOC and chlorophyll a
- Account for lake operations in model
- Fix short-comings of the existing model
- Capability to develop our own model
- Account for atmospheric deposition
- Lake Boundary Conditions
  - What is entering the lake? Chlorophyll a, other tributaries N, P and chlorophyll a
  - Are loads to the lake declining? (N, P and chlorophyll a)
  - Where is the best location (stable) to monitor inputs to the lake?

Falls Lake Watershed

- Characterize the distribution of loads
  - Load distribution (at jurisdictional boundaries)
  - What loads come from each jurisdiction
  - What are the actual loads distributed from throughout the watershed? Can we better understand sources by having a watershed model that is calibrated to measured loads at multiple locations? At jurisdictional boundaries?
  - Know loads by jurisdiction & tributary
  - Nutrient loading by jurisdiction and by subwatershed (2006 base and ongoing, current as of date certain)
  - Better unit loading rates that may vary by geography and by land use
- Tell us whether management efforts are succeeding (a vigorous effort)
  - Understand how management practices are affecting loads (individual and cumulative)
- Monitor Rainfall
  - Given that the model used rain data from RDU, would local monitoring of rainfall improve hydrologic calibration?
- Nutrient Mapping
- Sources Mapping
- Unknowns: Fertilizer, septic, sediment-attached P, atmospheric deposition
- Know the value of EACH individual management strategy (e.g., septic, ag). Do the BMPs work?
- Watershed Characterization
  - Distinguish sources of different types of nitrogen
  - Understand loads from forest and atmospheric deposition
  - Atmospheric deposition—coordinate with energy & air quality efforts with regard to nutrients
  - Forest is the largest component of the watershed. What are the actual nutrient loads from forests in the Triassic basin?

MUST DO

Falls Lake Monitoring and Modeling Goals and Objectives (September 7, 2010 Stakeholder Meeting)

What goals and objectives do you or your jurisdiction have for any new monitoring or modeling of Falls Lake or the Falls Lake watershed?

	Falls Lake	Falls Lake Watershed	
MUST DO		○ Measured load from forests (slate vs. Triassic) ○ Nutrient loading by source type, 2006 base and ongoing ○ What are the impervious cover characteristics of the watershed? (where is IC and how is it distributed?) ○ Which streams do not have intact riparian buffers?	**MUST DO**
NICE TO DO	• Consider emerging pollutants (endocrine disruptors, personal care products, cyanotoxins) • How much does water level fluctuation contribute to internal loading in the lake? • Alternatives to chlorophyll a as an indicator • Learn about fish populations and biota in upper and lower lake relative to chlorophyll a and turbidity (impairment)	• Understand (soils for) onsite wastewater attenuation rates • Nutrient trading tool (USDA, lbs N, lbs P, reductions)	**NICE TO DO**
NOT NOW	Nothing was placed in this category for the lake or watershed.		**NOT NOW**

Falls Lake Monitoring and Modeling Goals and Objectives (September 7, 2010 Stakeholder Meeting)

What goals and objectives do you or your jurisdiction have for any new monitoring or modeling of Falls Lake or the Falls Lake watershed?

MUST DO

Combined, Both or In-Between Goals and Objectives

- TRUST
- Work together, Do Good Things
    - One testing program accepted by all stakeholders and DWQ
    - Negotiate MOA or program with DWQ for entire monitoring program
    - Neutral & unbiased monitoring, management and oversight
- Stable Funding (no gaps in data collection) (timing longitudinal)
- Analyze process needs. Get Association
    - What does good long-term lake & watershed management look like? (account for droughts, pool re-allocation, hurricanes)
    - Ask Corps of Engineers to do research evaluating lake operations on water quality
    - Get Association together and let them determine accounting tools (instead of the Jordan Lake stakeholders)
- Clear system of water quality benchmarks. Relevant to decision-makers and the public.
- Understand current monitoring efforts
- Standardized methods, consistent and state approved.
- EPA & DWQ agreement on using correct & cost-effective study methods
- Translate/compare data collected using different methods (if possible)
- Know by 2017 (at least) where we are vis-à-vis Stage I.
- Gather new data for remodeling in 2018 (means we need to know which model will be used)
- Cost-effective, well-coordinated with other efforts
- Data is accepted by DWQ
- Define minimum data requirements
- Address data gaps
- Assess data being collected (current monitoring plans)
- Better definition of how data will be used to modify NMS
- Make sure our data can support decisions at a high level of certainty within regulatory time frame.

MUST DO

NICE TO DO

- Determine if modeling is as accurate as possible given state of science.
- Propose a new model(s) to address any identified deficiencies. Make sure flexible enough to incorporate new learning.

NICE TO DO

NOT NOW

Nothing was placed in this category.

NOT NOW

Upper Neuse Water Quality Monitoring Plan

Potential Objectives

Table 1. Objectives for a water quality monitoring plan as grouped into headings.

Sources/Dynamics of Nutrient Loading

- What is entering the lake? Chlorophyll a, other tributaries N, P and Chlorophyll *a*
- Are loads to the lake declining? (N, P and chlorophyll a)
- What is entering the lake? (Chlorophyll a, other tributaries (N, P, Chl a)
- Where is the best location (stable) to monitor inputs to the lake?
- Sources Mapping
- Unknowns: Fertilizer, septic, sediment-attached P, atmospheric deposition
- What are the impervious cover characteristics of the watershed? (Where is IC and how is it distributed?)
- Understand (soils for) onsite wastewater attenuation rates
- What are the actual loads distributed from throughout the watershed? Can we better understand sources by having a watershed model that is calibrated to measured loads at multiple locations? At jurisdictional boundaries?
- What loads come from each jurisdiction?
- Characterize internal lake load
- What is approximate nutrient loading into Falls Lake watershed from groundwater?
- Nutrient loads from groundwater discharge
- Lake boundary conditions (are loads to the lake declining (N, P, Chl a))?
- Understand how loads from agriculture (equine) differ from others (flow, composition, urban/suburban)
- Where is the best location (stable N, P, Chlorophyll a) to monitor inputs to the lake?
- Nutrient loading by source type. Base, ongoing, and current as of date.
- Distinguishing sources of different types of Nitrogen (i.e. residential, fertilizer vs. onsite wastewater)
- Watershed characterization
- Characterize sources better
- Measured load from forests (slate vs. Triassic)
- Nutrient loading by source type, 2006 base and ongoing

Nutrient Mapping

- Characterize the distribution of loads
- Load distribution (at jurisdictional boundaries)
- What loads come from each jurisdiction?
- What are the actual loads distributed from throughout the watershed? Can we better understand sources by having a watershed model that is calibrated to measured loads at multiple locations? At jurisdictional boundaries?
- Know loads by jurisdiction & tributary
- Nutrient loading by jurisdiction and by subwatershed (2006 base and ongoing, current as of date certain)
- Better unit loading rates that may vary by geography and by land use
- Nutrient trading tool (USDA, lbs N, lbs P, reductions)

Lake Response Timeline

- Given high internal loading in the lake, how will the lake respond to changes in the load?
- Data and analysis that can be used to forecast or "backcast" conditions
- What contribution of P (maybe N) does re-suspension have on the total nutrient load to be managed in the lake?

Lake Characterization

- Understand current condition of the lake
- Lake Boundary Conditions (are loads to the lake declining (N, P, Chl a)
- How much does water level fluctuation contribute to internal loading in the lake?
- Forest is the largest component of the watershed. What are the actual nutrient loads from forests in the Triassic basin?
- Understand loads from forest and atmospheric deposition
- Ask Corps of Engineers to do research evaluating lake operations on water quality
- Which streams do not have intact riparian buffers?
- Atmospheric deposition—coordinate with energy & air quality efforts with regard to nutrients
- Account for atmospheric deposition

Modeling Concerns

- Monitor Rainfall
- Given that the model used rain data from RDU, would local monitoring of rainfall improve hydrologic calibration?
- Determine if modeling is as accurate as possible given state of science.
- Propose a new model(s) to address any identified deficiencies. Make sure flexible enough to incorporate new learning
- Account for lake operations in model
- Fix short-comings of the existing model
- Capability to develop our own model
- Account for atmospheric deposition
- Gather new data for remodeling in 2018 (means we need to know which model will be used)
- What does good long-term lake & watershed management look like? (account for droughts, pool re-allocation, hurricanes)
- Better definition of how data will be used to modify NMS
- What are the least number of sites that would allow a remodel and use support assessment
- Data and analysis that can be used to forecast or “backcast” conditions
- New models needed
- Better unit loading rates that may vary by geography/use

Institutional Oversight

- Analyze process needs. Get Association
- Get Association together and let them determine accounting tools (instead of the Jordan Lake stakeholders)
- Define minimum data requirements
- One testing program accepted by all stakeholders and DWQ
- Know how DWQ is going to assess nutrient reductions for BMPs. Need to know requirements before assessing in projects (site specific before/after modeling?)

Regulatory Acceptance/QACC/QAPP

- One testing program accepted by all stakeholders and DWQ
- Negotiate MOA or program with DWQ for entire monitoring program
- Neutral & unbiased monitoring, management and oversight
- Data is accepted by DWQ
- Standardized methods, consistent and state approved.
- EPA & DWQ agreement on using correct & cost-effective study methods
- Implementable (fundable) plan that DWQ will accept

Management Effectiveness

- Tell us whether management efforts are succeeding (a vigorous effort)
- Understand how management practices are affecting loads (individual and cumulative)
- Know by 2017 (at least) where we are vis-à-vis Stage I.
- Know the value of EACH individual management strategy (e.g., septic, ag). Do the BMPs work?
- Tell us whether management efforts are succeeding; track success of NMS by source (agriculture, existing development, etc)
- Determine if BMPS are effective
- Focused sub-basin monitoring designed to isolate impacts from individual sources and improvements after BMPs implemented (to use to calibrate for basin future modeling efforts)
- Monitor BMPs

Emerging Contaminates

- Consider pollutants other than just nutrients (i.e. those that pose health risks to users of water)
- Consider emerging pollutants (endocrine disruptors, personal care products, cyanotoxins)
- Need to know levels of endocrine-disrupting chemicals, pharmaceuticals, and personal care products. Will help determine/reflect sources of input to the lake and watershed

Use Support Analysis

- Evaluate how well the land (public) meets needs (recreation) in watershed
- Evaluate Past, Present and Future Uses of the Lake
- Determine if existing water quality standards support existing uses. Are they too restrictive, too loose, or missing?
- Evaluate how well the lake meets existing uses. Water supply, aquatic life propagation, recreation (boating, swimming, fishing)
- Evaluate the degree to which the lake has, is, or can support all its authorized uses.
- Supports UAA (Use Attainability Assessment) or change in use (water quality standard) for upper Falls Lake

Public Education and Outreach

- Designation of Actions/Behaviors that residents, volunteers, and non-profits can do that won't cost taxpayers money
- Expand/Improve/Increase public awareness and participation in annual big sweep events; track totals
- Subsidize or incentivize residential composting; track # participants

Drinking Water

- Understand relationship between TOC, nutrients, and Chlorophyll a

Wildlife Management

- Learn about fish populations and biota in upper and lower lake relative to chlorophyll a and turbidity (impairment)
- Map urban stream syndrome (deeply incised streams)

Data Consolidation

- Make sure our data can support decisions at a high level of certainty within regulatory time frame.
- Translate/compare data collected using different methods (if possible)
- Stable Funding (no gaps in data collection) (timing longitudinal)
- Understand current monitoring efforts
- Cost-effective, well-coordinated with other efforts
- Address data gaps
- Assess data being collected (current monitoring plans)
- Develop data standards for monitoring data and tools; convert current monitoring from various sources

into a more common format • Clear system of water quality benchmarks, relevant to decision-makers and public

Table 2. Questions for a water quality monitoring plan generated with heading names.

Sources and Dynamics of Nutrient Loading/Nutrient Mapping • Identify sources of nutrients within and outside our combined regulatory purview. • For nutrients within regulatory purview, identify sources of nutrients by use and by jurisdiction. • For modeling, accounting for transport/attenuation/uptake as they relate to streams, for different media (i.e. groundwater, types of streams). • How might different land uses inform efficient monitoring regimes? • Better understanding of poorly quantified nutrient sources (sources not regulated); can we trust nutrient trading tools?
Lake Response • What short-term changes in phytoplankton and chlorophyll-a community composition occur with measured load reductions from watershed? • How important is internal nutrient loading vs. allocthonous loading in the lake? • What are the major influences on watershed and lake hydrology? • What are influences of hydrology on nutrient expression in lake?
Lake Characterization • Where are the nutrient source loads originating from within the lake and watershed? • How does nitrogen get processed in lake? • What level of nutrients can the lake process? • Differentiate mass loads from different sources in watershed.
Modeling Concerns • What type/quantity of monitoring data to use? • What models are needed/appropriate? • Who develops the model? • What is the goal of the model? • Frequency of review and recalibration? • Who interprets data and model output? • What is appropriate time for sampling?
Institutional Oversight and Regulatory Acceptance • What are standards that would be acceptable to DWQ and local governments? • Who will develop the standards? • What organization will have oversight and will this be by consensus?
Management Effectiveness • Perform targeted evaluations of BMP assumptions. • Are there things we can do to evaluate model effectiveness? • Is management effectiveness a core goal of water quality monitoring process? • Can data on management effectiveness help feed data for compliance? • Question of degree to which evaluating the management effectiveness a core goal? • Different levels of evaluation. • Are loads to lake declining?

- Goals discussed at this table:
    - Understand relationship between TOC and chlorophyll-*a*.
    - Gather data on chlorophyll-*a* and other parameters such that model can be run to determine whether Stage II is appropriate.
    - Gather data for a use attainability analysis.
    - Targeted evaluations of established BMP assumptions.

Emerging Contaminants

- Are there measurable levels of emerging contaminants? At wastewater treatment plant effluent? In Falls Lake? In drinking water?
- If so, what are the concentrations compared to other research?

Drinking Water

- Is there a correlation between TOC, nutrients, and chlorophyll-*a*?

Use Support

- What type of monitoring should be performed to determine use support?
- Can existing data generate answers for use support questions?
- What are existing uses or classes and what type of land uses help determine use, land use focus on monitoring?

Public Outreach and Education

- Can monitoring generate increased participation in public outreach?
- Can monitoring determine effectiveness of public outreach involvement efforts?
- What are the priorities for public education?
- Do grassroots efforts such as residential composting produce reductions in nutrients? Is this too small a piece to measure?

Data Consolidation

- Is standardizing a test method a good way to achieve data consolidation?
- Is standardizing a test method a good way to achieve collection methods?
- Can permit regulations be modified to allow data consolidation?
- Can data consolidation be used to reduce duplication of effort and reduce overall cost?
- Can data consolidation be used to address existing data gaps?
- Can data consolidation help ensure the right data are being collected at an acceptable frequency?

Overview of the UNRBA Monitoring Program

Table 1 UNRBA Monitoring Program Objectives

Number	Objective
1	Support lake response modeling
2	Support alternative regulatory options
3	Understand source allocation and jurisdictional loading

Table 2 UNRBA Monitoring Program Components

Monitoring Program Component	Data Use	UNRBA Objectives[1] Supported
Routine Monitoring		
Lake Loading at 18 stations	> Quantify lake loading inputs to the models	1
20 Jurisdictional boundary stations	> Demonstrate water quality at multiple locations for all UNRBA member organizations > Provide additional water quality observations in upper reaches of the watershed which may be used in the future to develop watershed loading models	3
Special Studies [Fiscal Year, July through June]		
Storm event sampling (SS.LR.1) [FY2015, FY2016]	> Provide additional monitoring data for comparing multiple methods for estimating loads to the model(s) and to assist in the selection of best method for estimating loads to Falls Lake > Provide additional water quality observations which may be used in the future to develop watershed loading models	1
Lake sediment evaluation (SS.LR.2) [FY2016]	> Collect lake bottom sediment cores to characterize nutrient flux rates for use in revised lake models > Update sediment nutrient flux rates in the model(s) > Understand lag times associated with watershed implementation and lake response > Support regulatory options	1
High flow sampling (SS.LR.3) [FY2015, FY2016, FY2017]	> Sample tributaries during storm events to characterize water quality data when loading to the lake is high > Provide a better understanding of the water quality conditions in stagnant areas and wetland complexes during high flow events > Refine loading estimates to the model(s) > Provide additional data for the development of a watershed model	1
Special Lake Studies (SS.LR.5) [FY2016 and FY2017]	**Water quality / velocity measurements at representative lake constriction points [FY2016]** > Provide data at a refined temporal scale for EFDC model calibration > Provide estimates of flux through the major lake segments for EFDC, BATHTUB, and empirical models > Provide data to support regulatory options that may include site specific criteria or use attainability analyses for specific lake segments **Bathymetry and Sediment Mapping [FY2017]** > Collect lake bathymetry data to define the model domain and support revisions to the lake model grid	1

Monitoring Program Component	Data Use	UNRBA Objectives[1] Supported
	> Characterize the depths of unconsolidated sediments along the lake bottom for comparison to sediment core data and estimated nutrient fluxes from the Lake Sediment Evaluation (SS.LR.2)	
Obtain light extinction data (SS.LR.7a and b) [FY2016]	> Provide a better understanding of the quality of the relationship between light extinction and Secchi depth in Falls Lake > Provide data to develop and calibrate EFDC and BATHTUB models	1
Basic evaluation of model performance (SS.LR.8) [FY2016]	> Use the existing EFDC and BATHUB models and Falls Lake Framework Tool to support future revisions to the Monitoring Program > Compare tributary load estimation methods to storm event data to support future model revisions > Develop a framework and preliminary network connections for the empirical model > Assess data needs for the empirical model	1
Tracking BMP Implementation, Inspections, and Repairs (SS.SA.1) [ongoing by each jurisdiction]	> Track information regarding description of each BMP, geographic position, parcel square footage, square footage by land use draining to the BMP, and BMP inspections and maintenance performed to document compliance with the rules and changes in watershed loading > May be used to inform future watershed modeling in terms of practices implemented	3
Obtain CAAE platform data (SS.RO.1) [FY2016 and FY2017]	> Provide additional data for the EFDC model calibration and development of the empirical model > Support potential development of alternative regulatory approach	2
Obtain fish monitoring data (SS.RO.2) [FY2015, FY2016, FY2017]	> Correlate water quality with fish population data collected by Wildlife Resources Commission > Assess the need for supplemental data needed in this area of "alternative regulatory approaches" as we move through this monitoring program (i.e. if WRC data isn't appropriate and we can't secure additional data from them (get them to do a special study), the UNRBA will generate the data needed (coordinated with WRC). > Provide data for the development of the empirical model > Support potential development of alternative regulatory approach	2
Obtain drinking water quality data (SS.RO.3) [FY2015, FY2016, FY2017]	> Provide estimate of forms of carbon throughout the lake for Falls Lake EFDC model refinement > Provide additional data for City of Raleigh regarding fluctuations in TOC concentrations > Determine whether TOC is generated primarily within Falls Lake or in the watershed > Support development of the empirical model by linking lake water quality to finished water quality and the drinking water designated use	1,2,3
Recreational Uses Assessment (SS.RO.4a and b) [FY2016 (4a)]	> Demonstrate that Falls Lake is supporting recreational uses and correlate use with fluctuations in water quality within Falls Lake > Provide data for the development of the empirical model > Support potential development of alternative regulatory approach	2
Preparation for and meetings with state and federal regulators (SS.RO.5) [FY2015, FY2016, FY2017]	> Legal support and Cardno participation in meetings with DWR and EPA to better understand agency requirements associated with special studies that will be used to support alternative regulatory options and development of the empirical model	2

Table 3 Anticipated Schedule and Sampling Frequencies for UNRBA Monitoring Program

Monitoring Program Component	FY2015 August 2014 - June 2015	FY2016 July 2015 - June 2016	FY2017 July 2016 - June 2017	FY2018 July 2017 - June 2018	FY2019 July 2018 - June 2019
Routine Monitoring					
Lake Loading at 18 stations	**Twice a month** for Ellerbe, Eno, Little, Flat, and Knap of Reeds; **Monthly** for all other locations.		**Monthly** for all locations	Frequency to be determined	
20 jurisdictional boundary stations	**Monthly** monitoring for all locations			Frequency to be determined	
Special Studies	**FY2015**	**FY2016**	**FY2017**	**FY2018**	**FY2019**
Storm event sampling	x	x			
Lake Sediment Evaluation[1]		x			
High flow event sampling	x	x	x	x	x
Water quality / velocity measurements at representative lake constriction points		x			
Bathymetry and sediment mapping			x		
Analyze historic light extinction data		x			
Collect light extinction data		x			
Basic evaluation of model performance		x			
Tracking BMP implementation, inspections, and repairs	x	x	x	x	x
Obtain CAAE platform data	x	x	x	x	x
Obtain fish monitoring data	x	x	x	x	x
Obtain drinking water quality data	x	x	x	x	x
Recreational uses assessment		x			
Preparation for and meetings with state and federal regulators		x	x	x	x

[1]This table reflects the schedule for the UNRBA Lake Sediment Evaluation. USEPA may conduct benthic chamber measurements of nutrient flux from the lake sediment during any or none of these monitoring years.

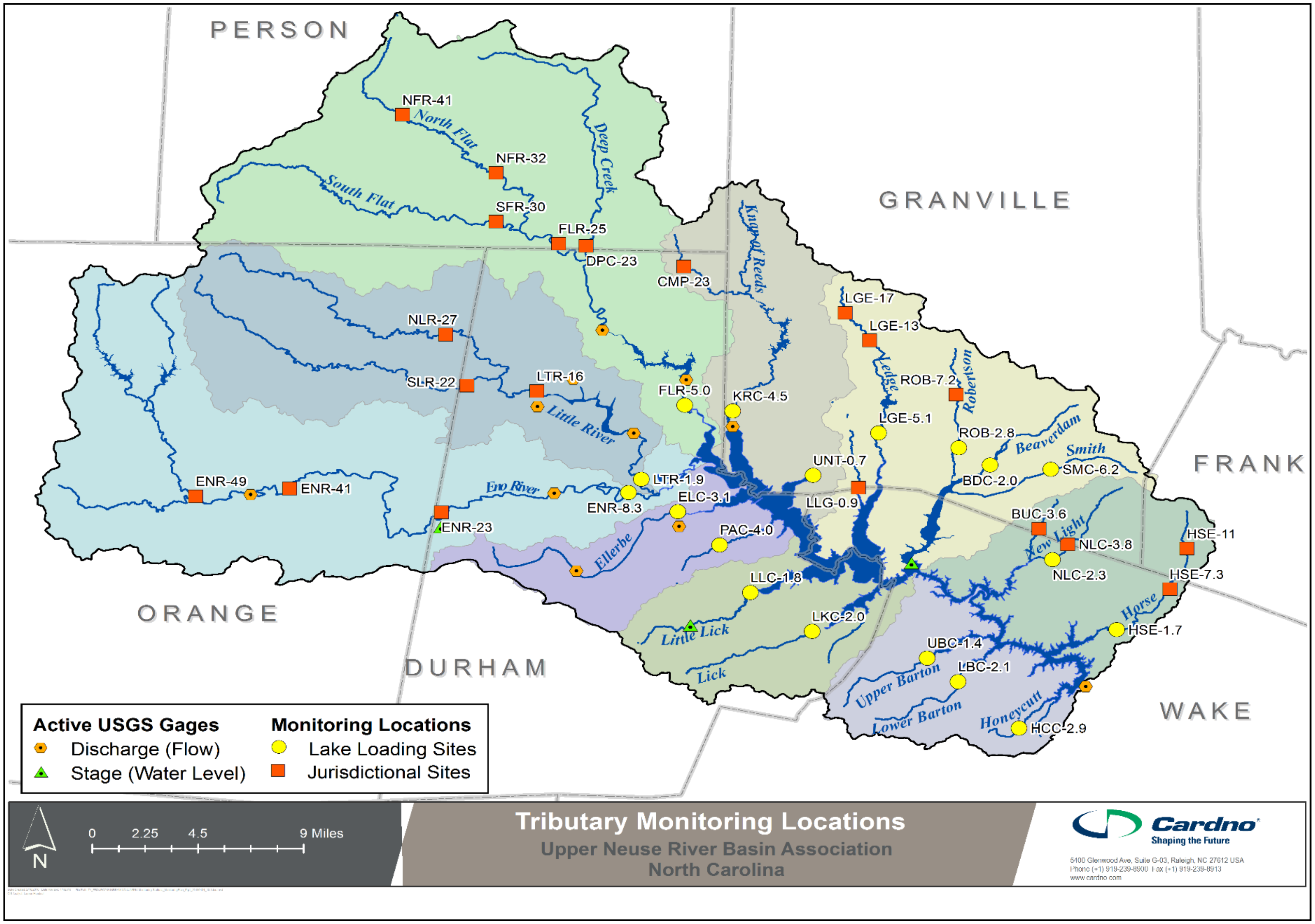

Figure 2 UNRBA Lake Loading and Jurisdictional Boundary Monitoring locations and Existing USGS Gages

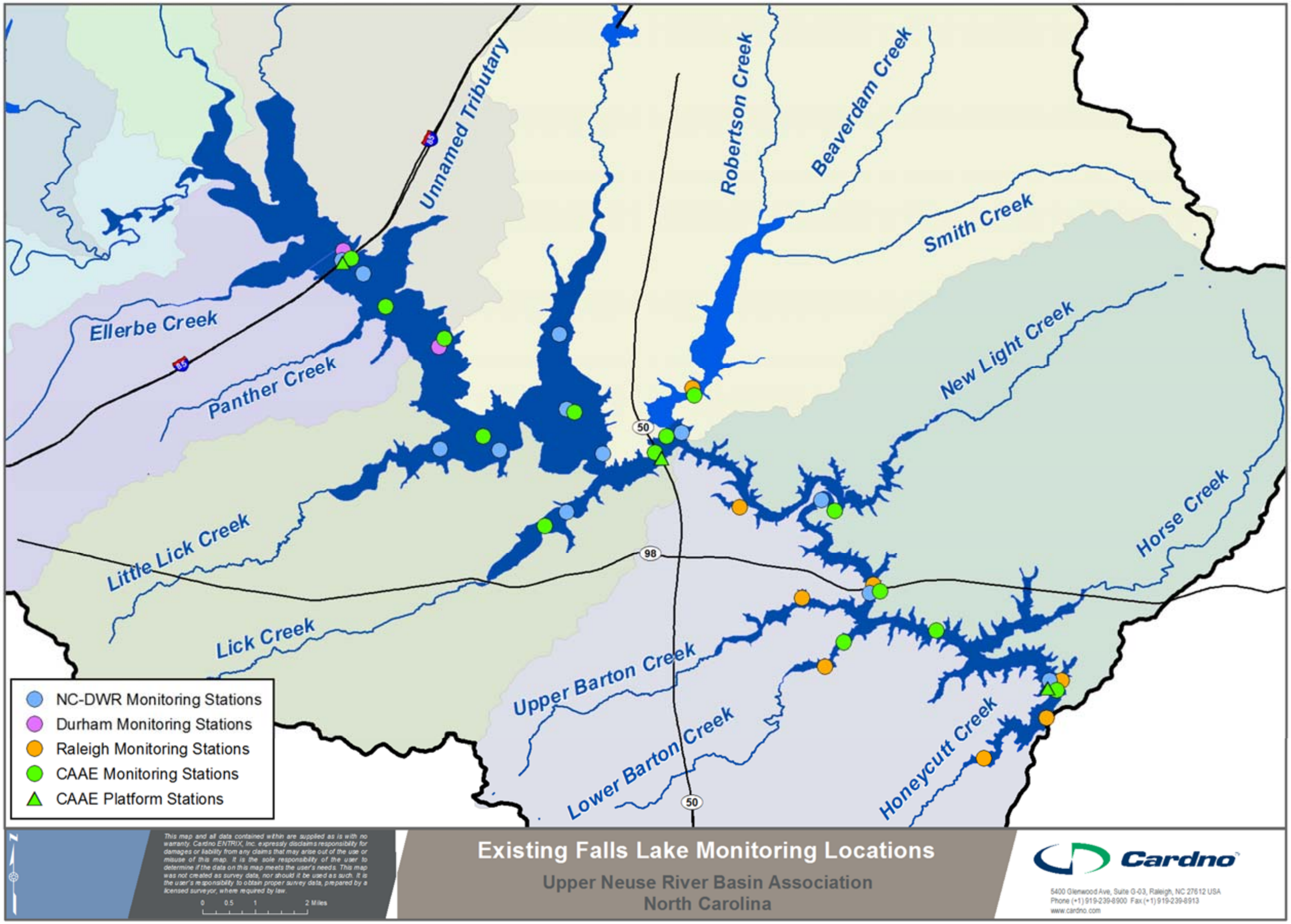

Figure 3 **Falls Lake DWR, CAAE, City of Raleigh, and City of Durham Monitoring Locations**

Table 4 Lake Loading Monitoring Locations

Name[1]	Waterbody	Road Crossing	Latitude	Longitude	Drainage Area (mi^2)
FLR-5.0	Flat River	at Old Oxford Highway	36.1319	-78.8280	169
ENR-8.3	Eno River	at Old Oxford Highway	36.0726	-78.8627	149
LTR-1.9	Little River	at Old Oxford Road	36.0817	-78.8547	104
KRC-4.5	Knap of Reeds Creek	at SGWASA WWTP	36.1280	-78.7985	41.9
ELC-3.1	Ellerbe Creek	at Glenn Road	36.0596	-78.8322	21.9
LGE-5.1	Ledge Creek	at Highway 15	36.1131	-78.7085	20.3
LLC-1.8	Little Lick Creek	at Patterson Road	36.0046	-78.7875	13.8
BDC-2.0	Beaverdam Creek	at Horseshoe Road	36.0913	-78.6399	12.7
NLC-2.3	New Light Creek	at Mangum Dairy Road	36.0270	-78.6013	12.3
ROB-2.8	Robertson Creek	at Brassfield Road	36.1030	-78.6592	12.0
HSE-1.7	Horse Creek	at Thompson Mill Road	35.9791	-78.5617	11.9
LKC-2.0	Lick Creek	at Southview Rd south of Hwy 98	35.9779	-78.7496	10.8
LBC-2.1	Lower Barton Creek	at State Road 1834 (Norwood Road)	35.9439	-78.6596	10.4
UBC-1.4	Upper Barton Creek	at Mt Vernon Church Road	35.9599	-78.6786	8.26
SMC-6.2	Smith Creek	at Lawrence Road	36.0884	-78.6024	6.30
UNT-0.7	Unnamed Tributary	at Northside Road	36.0843	-78.7489	3.43
PAC-4.0	Panther Creek	at end of Cooksbury Drive	36.0370	-78.8064	3.24
HCC-2.9	Honeycutt Creek	at Honeycutt Road	35.9126	-78.6221	2.76

[1]Name combines an abbreviation for the waterbody with an approximation of the distance upstream from Falls Lake (km).

Table 5 Parameters Measured Monthly at Lake Loading Sites

Parameter	Start Date	End Date
Field Measurements:		
Air temperature	Aug 2014	Aug 2015
Water temperature	Aug 2014	Ongoing
Specific conductance	Aug 2014	Ongoing
Dissolved Oxygen	Aug 2014	Ongoing
pH	Aug 2014	Ongoing
Reference-point tape-down	Jan 2015	Ongoing
Dye velocity	Jan 2015	Ongoing
Laboratory Analyses:		
Total Kjeldahl nitrogen	Aug 2014	Ongoing
Soluble Kjeldahl nitrogen	Aug 2014	Ongoing
Nitrate + nitrite	Aug 2014	Ongoing
Ammonia	Aug 2014	Ongoing
Total phosphorus	Aug 2014	Ongoing
Total soluble phosphorus	Aug 2014	Ongoing
Orthophosphate	Aug 2014	Ongoing
Total organic carbon	Aug 2014	Ongoing
Dissolved organic carbon	Aug 2014	Jun 2016
Chlorophyll *a*	Aug 2014	Ongoing
Total suspended solids	Aug 2014	Ongoing
Volatile suspended solids	Jul 2015	Ongoing
Color (platinum cobalt)	Aug 2014	Jun 2016
Visible absorbance at 440nm	Aug 2014	Ongoing
UV absorbance at 254nm	Aug 2014	Ongoing
5-day carbonaceous biochemical oxygen demand	Aug 2014	Jun 2016

Table 6 Current Lake Sampling by DWR, Cities of Durham and Raleigh, and CAAE[1]
Frequencies are provided in parentheses: M-monthly, W-weekly, D-subdaily.

Samples	DWR	City of Durham[2]	City of Raleigh	CAAE
TOC	Photic Zone Composite (M)	Photic Zone Composite (W)	Surface (M)	Monthly with seasonal increase in frequency at the three platforms (I-85, Hwy 50, and Raleigh Intake), variable frequency elsewhere[3]
DOC	Photic Zone Composite (M)[5]	-	-	-
$CBOD_5$	Photic Zone Composite (M)[5]	-	-	-
Color	Photic Zone Composite (M)[5]	-	-	-
Chlorophyll a	Photic Zone Composite (M)	Photic Zone Composite (W)	Surface (M)	Hwy 85, Hwy 50, and Raleigh Intake 1-2 meters, 2x/month Variable sampling frequency at other locations
TN	Photic Zone Composite (M)	Photic Zone Composite (W)	Surface (M)	Monthly with seasonal increase in frequency at the three platforms (I-85, Hwy 50, and Raleigh Intake), variable frequency elsewhere[3]
TKN	Photic Zone Composite (M)	Photic Zone Composite (W)	Surface (M)	Monthly with seasonal increase in frequency at the three platforms (I-85, Hwy 50, and Raleigh Intake), variable frequency elsewhere[3]
NO2 + NO3	Photic Zone Composite (M)	Photic Zone Composite (W)	Surface (M)	Monthly with seasonal increase in frequency at the three platforms (I-85, Hwy 50, and Raleigh Intake), variable frequency elsewhere[3]
NH3	Photic Zone Composite (M)	Photic Zone Composite (W)	-	Variable
TP	Photic Zone Composite (M)	Photic Zone Composite (W)	Surface (M)	Monthly with seasonal increase in frequency at the three platforms (I-85, Hwy 50, and Raleigh Intake), variable frequency elsewhere[3]

Samples	DWR	City of Durham[2]	City of Raleigh	CAAE
Orthophosphorus	-	Photic Zone Composite (W)	-	-
Ultraviolet Absorbance (UVA) at 254 nm	Photic Zone Composite (M)[5] (Analyzed by UNRBA contract laboratory)	-	-	-
Turbidity	Photic Zone Composite (M)	-	Surface (M)	-
TSS	Photic Zone Composite (M)[5]	-	-	Monthly with seasonal increase in frequency at the three platforms (I-85, Hwy 50, and Raleigh Intake), variable frequency elsewhere[3]
VSS	Photic Zone Composite (M)[6]			
pH	Depth Stratified (M)	Depth Stratified (W)	Surface (M)	Depth Stratified (M,D)[4]
Conductivity	Depth Stratified (M)	Depth Stratified (W)	Surface (M)	Depth Stratified (M,D)[4]
Dissolved oxygen	Depth Stratified (M)	Depth Stratified (W)	Surface (M)	Depth Stratified (M,D)[4]
Temperature	Depth Stratified (M)	Depth Stratified (W)	Surface (M)	Depth Stratified (M,D)[4]
Algal groups	Photic Zone Composite at three stations (M)	-	-	-

[1] Each program is responsible for their own quality assurance practices.

[2] The City of Durham monitors its Falls Lake stations during the months of April through October of each year. Sites are not monitored from November through March.

[3] Data are available for a number of CAAE sites which are either no longer sampled, are sampled only in summer months or have variable sampling frequency for these parameters.

[4] At the three platform sites, these data are collected at multiple depths several times per day. At other sites these are typically collected monthly.

[5] At UNRBA's request, DWR added this parameter to their monthly sampling starting in October 2014.

[6] At UNRBA's request DWR added this parameter to their monthly sampling starting in September 2015.

Table 7 Jurisdictional Boundary Monitoring Locations

Name	Waterbody and Location	Boundary	Latitude	Longitude	Drainage Area (mi^2)
ENR-49	Eno River at Dimmocks Mill Road	upstream of Hillsborough	36.0701	-79.1295	60.5
ENR-41	Eno River at Hwy 70 and Riverside Drive	downstream of Hillsborough	36.0754	-79.0716	73.2
ENR-23	Eno River at Cole Mill Road	downstream of Orange County	36.0593	-78.9780	121
NLR-27	North Fork Little River at New Sharon Church Road	between Orange and Durham Counties	36.1802	-78.9754	21.9
SLR-22	South Fork Little River at Guess Road (Hwy 157)	between Orange and Durham Counties	36.1455	-78.9622	37.4
LTR-16	Little River at Johnson Mill Road	upstream of City of Durham	36.1416	-78.9193	78.3
NFR-41[1]	North Flat River at North Flat River Church Road	downstream of Roxboro	36.3295	-79.0020	12.7
NFR-37[2]	North Flat River at US 501	downstream of Roxboro	36.3106	-78.9694	15.8
NFR-32	North Flat River at Helena-Moriah Road	Person Co. before confluence with South Flat	36.2890	-78.9429	32.8
SFR-30	South Flat River at US 501 / NC 57	Person Co. before confluence with North Flat River	36.2568	-78.9443	54.4
FLR-25	Flat River at Moores Mill Rd	downstream of Person county	36.2419	-78.9058	102
DPC-23	Deep Creek at Smith Road	downstream of Person County	36.2403	-78.8889	32.1
CMP-23	Camp Creek at Camp Butner	between Durham and Granville Counties	36.2095	-78.8053	4.99
LLG-0.9	Little Ledge Creek at Old Weaver Trail	downstream of Granville	36.0759	-78.7210	3.74
LGE-17	Ledge Creek at Old Rte 75	downstream of Stem	36.1949	-78.7292	1.79
LGE-13	Ledge Creek at W Lyon Station Road	upstream of Butner	36.1761	-78.7141	3.49
ROB-7.2	Robertson Creek at Sam Moss Hayes Road	upstream of Creedmoor	36.1392	-78.6608	4.43
BUC-3.6	Buckhorn Creek at Buckhorn Lane	between Granville and Wake Counties	36.0481	-78.6097	1.21
NLC-3.8	New Light Creek at Bold Run Hill Road	between Granville and Wake Counties	36.0375	-78.5921	9.90
HSE-5.7[3]	Horse Creek at Jenkins Rd	downstream of Franklin County	35.9947	-78.5371	9.61
HSE-7.3	Horse Creek at Purnell Rd	upstream of Wake Forest	36.0071	-78.5291	7.11
HSE-11	Horse Creek at Green Rd	downstream of Franklin County	36.0345	-78.5186	3.88

[1] NFR-41 was added in July 2015 to replace NFR-37.

[2] NRF-37 was suspended after June 2015 due to safety and accessibility concerns.

[3] HSE-5.7 was sampled temporarily in May and June of 2015 while HSE-7.3 was inaccessible due to construction.

Table 8 Parameters Measured Monthly at Jurisdictional Boundary Sampling Locations

Field Measurements	Laboratory Analyses
Water temperature Air temperature (*suspended Aug 2015*) Specific conductance Dissolved oxygen pH Reference-point tape-down *(added Jan 2015)* Dye velocity *(added Jan 2015)*	Total Kjeldahl nitrogen Nitrate + nitrite Ammonia Total phosphorus Total organic carbon[1] Total suspended solids

[1]As of July 2016, TOC is analyzed quarterly at the jurisdictional stations; all other parameters continue to be analyzed monthly.

Table 9 Special Studies and Data Use, Importance, and Timing of Study Implementation

Study ID	Special Study Description	How information will be used by UNRBA and why it is important to the UNRBA	Estimated Duration[1]
Lake Response Modeling (Loading Estimation)			
SS.LR.1	Storm event sampling and comparison of loading methods	Compare the accuracy of tributary load estimation methods (e.g., various LOADEST options or WQ statistical model) to loads measured during storm event sampling. The TN and TP load estimate doubles depending on the method used as shown in the Model Sensitivity TM. Estimating lake loads based on the most accurate method will result in substantially more accurate model predictions and increased confidence in resulting Stage II targets.	2 - 4 storms per year, each at one site. Sites will vary for each storm. This study was conducted in FY2015 and FY2016 and will not be continued in FY2017.
SS.LR.2	Evaluate lake sediment quality, estimate and measure internal loading from lake sediments and measure other inlake processes	Improve accuracy and calibration of lake models. Cardno is currently working with Dr. Marc Alperin at UNC on a sediment core sampling program at up to 20 sites in Falls Lake. The analysis of porewater and sediment concentrations will allow for the estimation of sediment flux of ammonia and phosphate. In addition, the UNRBA has petitioned EPA to conduct SOD and nutrient flux chamber measurements at three locations in Falls Lake, which is expected to occur in monitoring year 3, 4, or 5. These studies will provide data to support lake modeling.	Evaluate lake sediment quality and estimate benthic flux in FY2015 and FY2016 in cooperation with UNC. UNRBA and DWR have cooperatively petitioned EPA to conduct in situ measures for Falls Lake (benthic chamber work and inlake processes). This study could occur during the summer months of any monitoring year.
SS.LR.3	High flow event sampling	High flow event sampling at tributaries will provide characterization of water quality when loading to the lake is high. The purpose of the high flow monitoring is to determine influence of storm flows on water quality concentrations at the largest tributaries and wetland influenced lake loading sites and select major lake loading stations. The data will be used to determine a likely "range" in nutrient concentrations and loading associated with storm flows.	FY2015, FY2016, FY2017, FY2018, FY2019 (optional)

Study ID	Special Study Description	How information will be used by UNRBA and why it is important to the UNRBA	Estimated Duration[1]
SS.LR.5	Special Lake Studies: Water quality / velocity measurements at representative lake constriction points And Bathymetry and sediment mapping	Provide data at a refined temporal scale to constrain model calibration that will occur in the future and provide estimates of flux through the major lake segments. And Collect lake bathymetry data to define the model domain and support revisions to the lake model grid Characterize the depths of unconsolidated sediments along the lake bottom for comparison to sediment core data and estimated nutrient fluxes from the Lake Sediment Evaluation (SS.LR.2).	FY2016 And FY2017
SS.LR.7a	Analyze historic light extinction data	Light is an important limiting factor for algal growth, and the lake models can be sensitive to light availability in terms of predicting algal growth. Analyze historic data (if available) to determine adequacy of using Secchi depth as a surrogate for light extinction.	FY2016
SS.LR.7b	Collect light extinction data	If historic data are not available, or the data indicates such variability that additional data collection is warranted, collect light extinction data in Falls Lake at each lake monitoring location.	FY2016 (data collected by DWR)
SS.LR.8	Basic evaluation of model performance	Use the existing EFDC and BATHTUB models and Falls Lake Framework Tool to support revisions to the Monitoring Program for FY2017. Compare tributary load estimation methods to storm event data. Develop a framework and preliminary network connections for the empirical model.	FY2016
Source Allocation: Determining Loading from Different Watershed Sources			
SS.SA.1	Tracking BMP Implementation, Inspections and Repairs	The following information should be collected: description of each BMP, geographic position, parcel square footage, square footage by land use draining to the BMP, and BMP inspections and maintenance performed. The Nutrient Scientific Advisory Board (NSAB) is currently establishing guidance regarding data collection efforts for BMPs that will be needed to calculate credits. To continue receiving nutrient loading credits from BMPs, local governments should inspect and repair BMPs on an annual basis.	This information should be tracked annually by member jurisdictions.

Study ID	Special Study Description	How information will be used by UNRBA and why it is important to the UNRBA	Estimated Duration[1]
Support of Regulatory Options - Linkage of Water Quality with Designated Uses			
SS.RO.1	Obtain profile data from three Center for Applied Aquatic Ecology (CAAE) monitoring stations (I-85, Highway 50, and Raleigh Intake).	Supports regulatory options and structural equation/ Bayesian modeling, and lake model calibration. Provides data needed to support development of site-specific water quality criteria or a sub-classification use attainability analysis.	FY2015, FY2016, FY2017, FY2018, FY2019
SS.RO.2	Obtain fish monitoring data collected by WRC at DWR Lake monitoring stations (or at the three CAAE locations)	Support regulatory options and structural equation/ Bayesian modeling. Correlates fish population, size and length with water quality conditions in the three main segments of the lake.	FY2015, FY2016, FY2017, FY2018, FY2019
SS.RO.3	Obtain drinking water quality data from the City of Raleigh to correlate water quality (nutrients, chlorophyll *a*, TOC, DOC, SUVA, and color) at the intake to finished water quality testing performed by Underwriters Laboratories (UL) (taste and odor and DBPs)	Support regulatory options and structural equation/Bayesian modeling. Provides data to identify how water quality at the intake is linked with disinfection byproduct formation and taste and odor issues in the finished water.	FY2015, FY2016, FY2017, FY2018, FY2019
SS.RO.4a	Recreational Uses Assessment	Support regulatory options and structural equation/Bayesian modeling to correlate lake water quality with recreational use: conduct initial research to inform discussions with regulators and develop survey protocols.	FY2016
SS.RO.5	Coordination with regulatory agencies in the design and implementation of studies associated with regulatory options.	Preparation of a strategy and presentation of materials for meetings and discussions with EPA Headquarters, EPA Region 4 and DWR in order to discuss agency positions concerning alternate regulatory approaches and to help identify the kinds of data that may be needed to support such approaches. These meetings and discussions will help identify and define future studies needed to develop the data for supporting alternate regulatory submissions by the UNRBA.	FY2015, FY2016, FY2017, FY2018, FY2019

[1] FY indicates the UNRBA's Fiscal Year, which runs from July through June. FY2015, for instance, included July 2014 through June 2015.

Overview of the Modeling Program (Year 1)

Table 10 Scope of Work for Year 1 of the Modeling and Regulatory Support Contract

Component
1. Kickoff meeting with watershed stakeholders and agency staff
2. Evaluation and selection of lake and watershed modeling packages
3. Development of conceptual plan for the multi-modeling approach
4. Develop the Modeling QAPP
5. Develop the two-year work plan (October 2017 through September 2019)
6. Revise the Description of Modeling Framework (previously approved by DWR)

Types of Modeling Packages Being Considered

- Watershed loading models predict the amount of pollutant generated from nonpoint sources (land uses, atmospheric deposition, onsite wastewater treatment, fertilizer application, etc.) and point sources (permitted dischargers such as wastewater treatment plants). These models may be empirical (data driven) or mechanistic (process based). Watershed loading models are often linked to downstream water quality models that predict the water quality in a receiving waterbody such as a river or lake. The UNRBA will evaluate approximately ten watershed modeling packages and select one or two models to support the reexamination effort.
- Lake nutrient response models predict water quality in a lake or reservoir in response to loading from the watershed, atmosphere, and point sources. Like watershed models, they may be either empirical or mechanistic. Lake response models should account for hydrologic inputs (tributary inflows, precipitation to the lake surface, point source discharges) and outputs (flow over the dam or through outlet structures, evaporation from the lake surface, and water withdrawals). Lake nutrient response models predict the growth of algae by simulating nutrient concentrations, light availability, and hydrologic residence time. Some lake nutrient response models account for internal nutrient loading from the lake bottom sediments. The UNRBA will evaluate approximately seven lake nutrient response modeling packages and select two or three models to support the reexamination effort.
- While watershed loading and lake nutrient responses models are often developed to predict nutrient loads and changes in water quality parameters, they typically do not address attainment of designated uses or key questions of concern from the public: Is the water safe to swim in? Will the lake support a healthy fish population? The UNRBA reexamination strategy includes an empirical/probabilistic/Bayesian model to link lake water quality to designated uses. Figure 4 shows the conceptual framework for this model and demonstrates how various water quality monitoring parameters and other information about the lake and water treatment plant characteristics may be used to evaluate compliance with the Safe Drinking Water Act, impacts to the recreational and aquatic life/wildlife designated uses, and compliance with water quality criteria. Because some of the information to populate this model may be difficult or costly to measure, expert opinion is often incorporated in the model. The UNRBA has identified subject matter experts in the fields of water chemistry, lake processes, drinking water treatability, and evaluation of impacts to recreational uses to support this component of the reexamination.

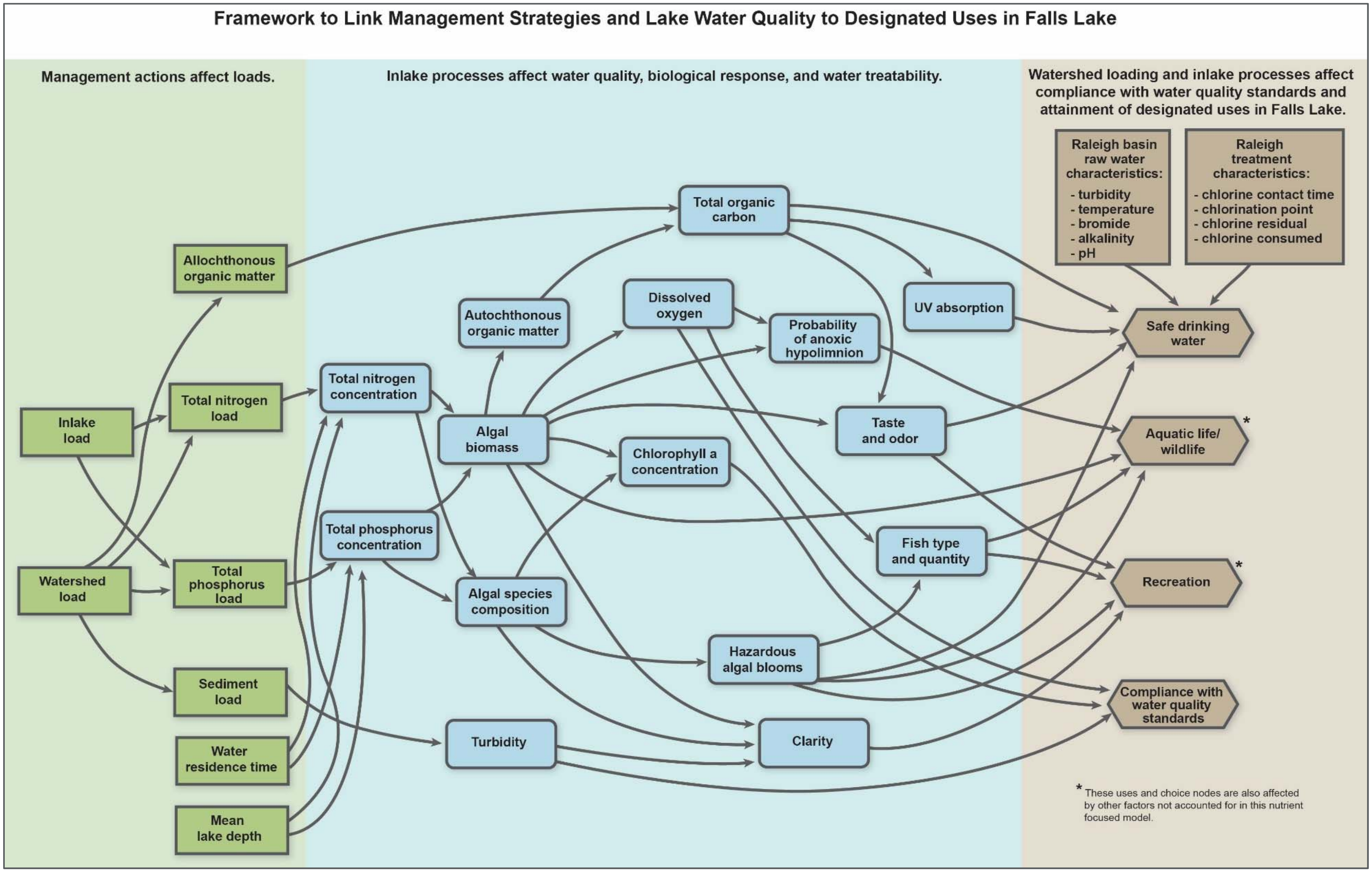

Figure 4 **Conceptual Diagram for the Empirical/Bayesian Falls Lake Model to Link Water Quality to Designated Uses**